IMPROVED
METHODS, TECHNIQUES, AND EQUIPMENT
FOR CLEANING EGGS

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PREFACE

This report covers the second phase of a research project directed toward developing improved egg cleaning equipment. This phase of the project was carried out in cooperation with the University of California, Agricultural Experiment Station, at Davis. It involves field tests of an experimental egg cleaner under operating conditions in a commercial egg grading and packing plant. The experimental equipment was designed, constructed, and laboratory tested under a research contract with the University, the results of which were reported in Marketing Research Report No. 740, "The Bacteriological, Chemical, and Physical Requirements for Commercial Egg Cleaning," by A. W. Brant, Phoebe Betty Starr, and John A. Hamann. Patentable features of the experimental equipment are in the process of preparation for application of patent.

The tests were conducted in a typical commercial egg grading and packing plant under the direct supervision of John A. Hamann, investigations leader, Transportation and Facilities Research Division, Agricultural Research Service, an author of this report.

Appreciation is expressed to the management of the egg grading and packing plant that made its facilities, equipment, personnel, and product available for the tests. The valuable suggestions and assistance furnished by Phoebe Betty Starr of the Food Science and Technology Department of the University of California are also acknowledged.

Trade names are used in this publication solely to provide specific information. Mention of a trade name does not constitute a guarantee or warranty and does not signify that the product is approved to the exclusion of other comparable products.

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IMPROVED METHODS, TECHNIQUES, AND EQUIPMENT FOR CLEANING EGGS

By Roger E. Walters, Robert O. Robbins, A. W. Brant, and John A. Hamann[1]

SUMMARY

Eggs with sound shells can be cleaned effectively with minimal spoilage hazard and shell damage without affecting internal egg quality. Slightly more than twice as many dirty eggs were cleaned by an experimental cleaner as were cleaned by the average commercial egg washer. The cleaning effectiveness averaged 78 percent on the experimental equipment and 35.9 percent on commercial units. Shell damage created by the experimental washer (1.89 percent) averaged about half of the average breakage in commercial machines (3.42 percent). Therefore, based on cleaning 250 cases of soiled eggs, a gain of $235 a day is possible if we assume that (1) an operating speed of 20 cases per hour is maintained; (2) the interpretation of clean and soiled eggs is based on the USDA standards of quality; (3) an average performance on commercial equipment is involved; and (4) average egg price differential of 7 cents a dozen for clean vs. dirty eggs and 12 cents a dozen for sound shell vs. cracked eggs are used. In addition, spoilage was virtually eliminated (only 0.6 percent spoilage in 8 weeks for farm-run eggs).

Design details and general recommendations for egg washing are given in this report.

The experimental cleaner has a number of design features not found in existing washers: Egg wetting before washing; fogger-type nozzles; low water volume; high-pressure cutting sprays; rotating brushes with the drive shaft parallel to the conveyor spools so that the bristles are perpendicular to the direction of egg travel; abrasive impregnated brushes; an egg spinning device to increase contact between the egg and the brush; and a separate conveyor in the drying unit. Other features not widely used are shaped brushes, a detergent metering device, and nonrecirculated wash water.

BACKGROUND

Cleaning soiled eggs has been a major problem confronting the poultry industry for many years. Early methods involved manually buffing each egg with an abrasive material, such as sandpaper or emery cloth, attached to a shoe polishing buffer, or wiping each egg clean with a wet cloth. These methods were used when laying flocks were comparatively small, and the chore of cleaning eggs was usually a family effort. As the farm flocks became larger and more eggs required cleaning, mechanical aids were introduced to lessen the time-consuming job. Such devices as motor-driven buffers, abrasive-type belts, and "wet" washers were introduced. The washers were not included in the grading and packing line; they were generally either the single-file, wet-brush type of washer or the tank type capable of holding a basket of eggs (about 15 dozen) submerged in agitated heated water containing a cleaning compound.

Larger capacity tank-type machines were used in large-scale egg breaking operations. Large-scale cleaners, conveyor fed (with eggs six abreast), using a dry or wet sand slurry, were also tried. The washing operations generally included a rinse and some provision for drying the eggs.

[1] Roger E. Walters, agricultural engineer, Robert O. Robbins, industrial engineer, and John A. Hamann, investigations leader, were all in the Transportation and Facilities Research Division, Agricultural Research Service, at the time of this study. Mr. Robbins left the ARS before the report was published. A. W. Brant, food technologist, is with the University of California.

Because of high labor requirements of the manual methods and the small "out-of-line" cleaner, plus the high breakage rates, spoilage hazard, and expensive equipment wear in the cleaners using sand slurry, the industry turned to mechanized in-line washing using either brush or water spray. This practice has become almost universal in the United States egg industry.

Commercial shell egg washers that are available can be described as the oscillating-brush type, the cutting-spray type, and the rotating brush type (figs. 1, 2, and 3).

There are differences in the designs of the washers with oscillating brushes. On one model, the brushes are shaped to fit the contour of the egg; on another, the brushes are not shaped to fit the egg and various brush motions are used; on others, the brushes can be adjusted for more or less contact with the eggs.

The cutting-spray washers have a large number of high volume nozzles, and the water is recirculated. Rotating-brush washers require the eggs be placed in single file to pass between two counter-rotating brushes, which are parallel to the path of the eggs. The single-file arrangement frequently limits the capacity of these machines because of the length of brush required for handling high production rates.

The sand slurry type of cleaner uses sand abrasion to remove the soil from the egg shell. In one such machine wet sand is moved by bucket elevators to hoppers directly over the egg conveyor. Small quantities are then metered onto a pair of high speed counter-rotating paddle wheels that cause the sand to strike the egg with sufficient force to clean the shell. After the spent sand has passed over the egg shell, it falls into a reservoir where it is heat sanitized and ready for re-use.

The labor requirements for cleaning eggs have been reduced considerably in recent years by eliminating much of the rehandling. Breakage has been reduced by improving machine design. Tests in an early phase of this study showed, however, that commercial egg washers, as operated by their owners, left much to be desired in cleaning ability, sanitation, and in some cases, level of breakage. This situation and the many inquiries (from industry and from within USDA) for a safe and effective method of washing eggs, prompted this research.

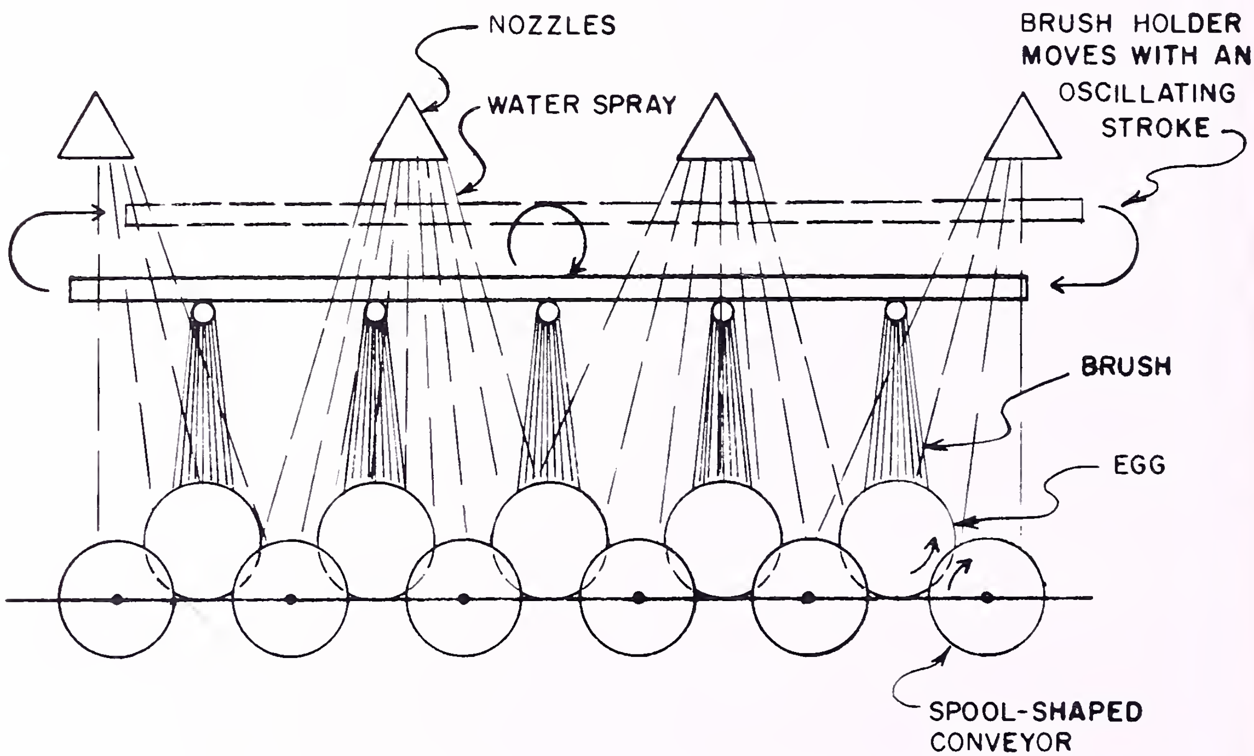

FIGURE 1.—Schematic sectional drawing of the oscillating brush-type washer.

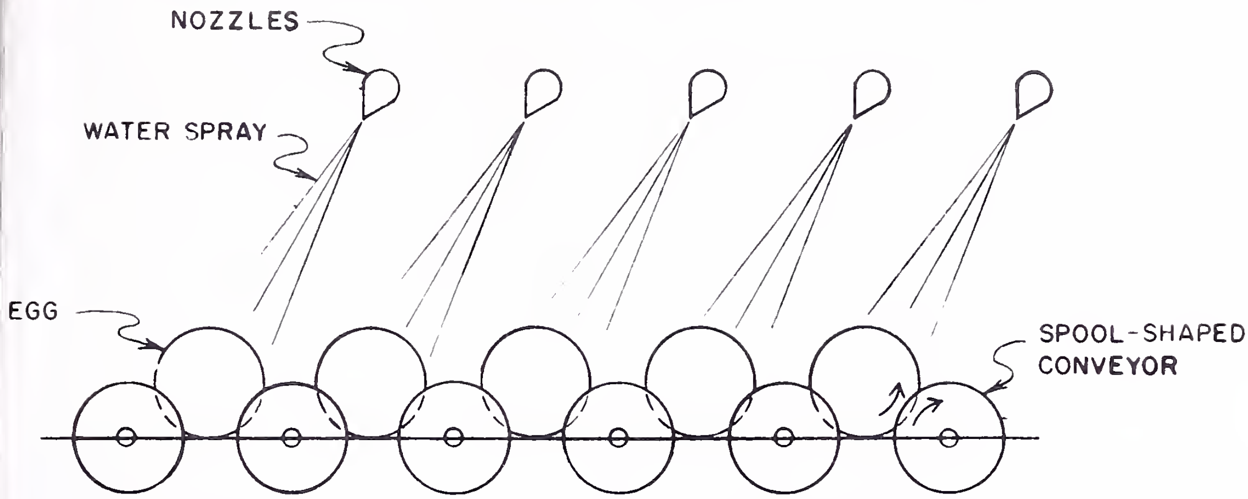

FIGURE 2.—Schematic sectional drawing of the cutting-spray type of washer.

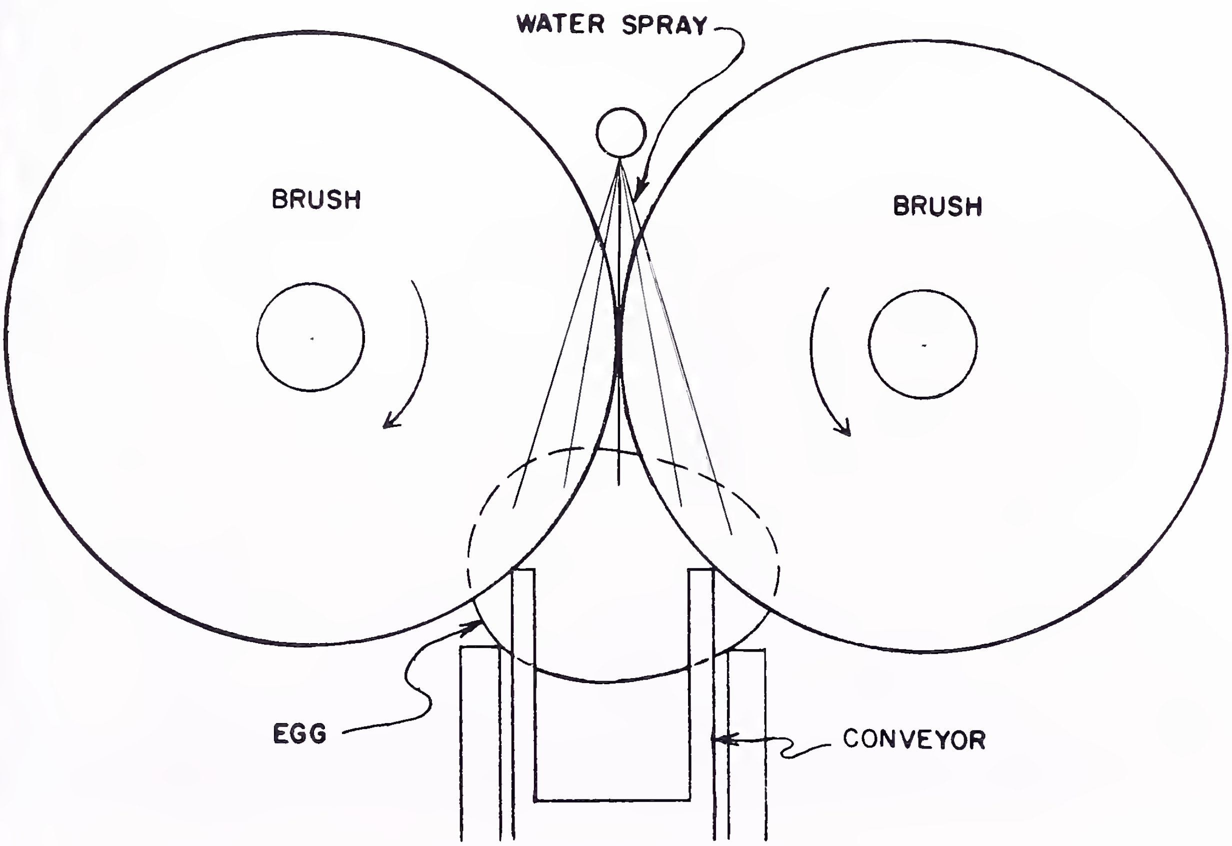

FIGURE 3.—Schematic sectional drawing of the rotating-brush type of washer.

The first phase of the research involved laboratory studies to determine the time, temperature, and bacteriological parameters for washing soiled eggs with minimum spoilage and loss in quality, testing the effectiveness of commercial cleaners, and designing, constructing, and testing an experimental cleaner.[2]

In these tests the following were the most significant findings: (1) A positive temperature differential of at least 20°F. should be maintained between the egg and the cleaning medium to minimize spoilage; (2) exposing eggs to high bacterial number (for example, in recirculated cleaning water) induced spoilage even when optimum temperature relationships existed between the egg and washing media; (3) cleaning effectiveness of brush bristles can be increased by the addition of an abrasive material; (4) transfer of eggs to a dry conveyor materially shortens the drying cycle; and (5) prewash wetting of eggs for 30 seconds improves cleaning. The phase of work reported here involved the testing and evaluation of the experimental egg cleaner under commercial conditions.

DESCRIPTION OF EXPERIMENTAL EGG CLEANER

The experimental cleaner consists of two components, the washer and the dryer, connected in tandem to provide a single-unit effect (fig. 4). The washing section was approximately 12 feet long and the dryer was approximately 5½ feet long. They were both 17 inches wide.

The frame of the machine, designed originally as a commercial egg conveyor (Seymour Spoolators No. 203–2 and 203–7 were used), was modified to accommodate the washer and dryer. Separate conveyors were used for the washing and drying components. They were connected by a device for transferring eggs from one conveyor to the other (fig. 5). The common drive for the conveyors on these units provided an alternating stop and go pattern similar to that used on most mechanized grading lines.

Washer

The washer had four principal sections: Egg loading and shell wetting area, water spray area for loose dirt removal, scrubbing area for removal of adhering dirt and stains, and rinsing area (fig. 6 and figs. 14–18, appendix).

[2] BRANT, A. W., STARR, PHOEBE B., and HAMANN, JOHN A. THE BACTERIOLOGICAL, CHEMICAL, AND PHYSICAL REQUIREMENTS FOR COMMERCIAL EGG CLEANING. U.S. Dept. Agr. Mktg. Res. Rpt. No. 740, 21 pp., illus. 1966.

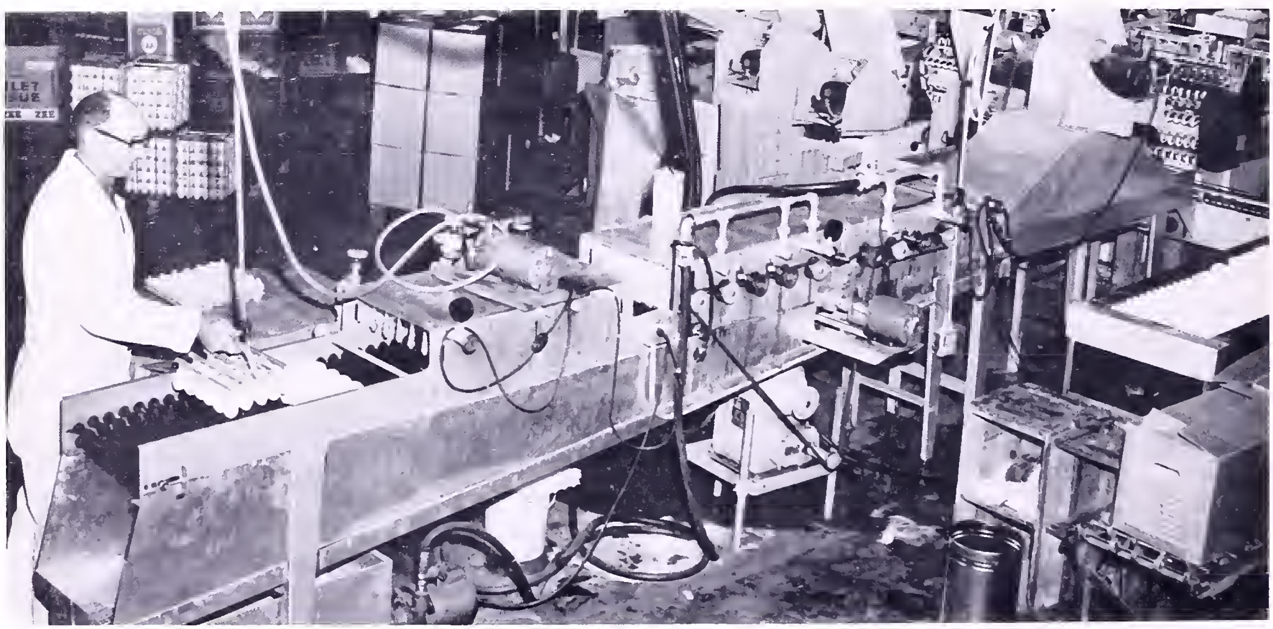

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FIGURE 4.—Experimental egg washer being loaded during tests in a commercial egg grading and packing plant.

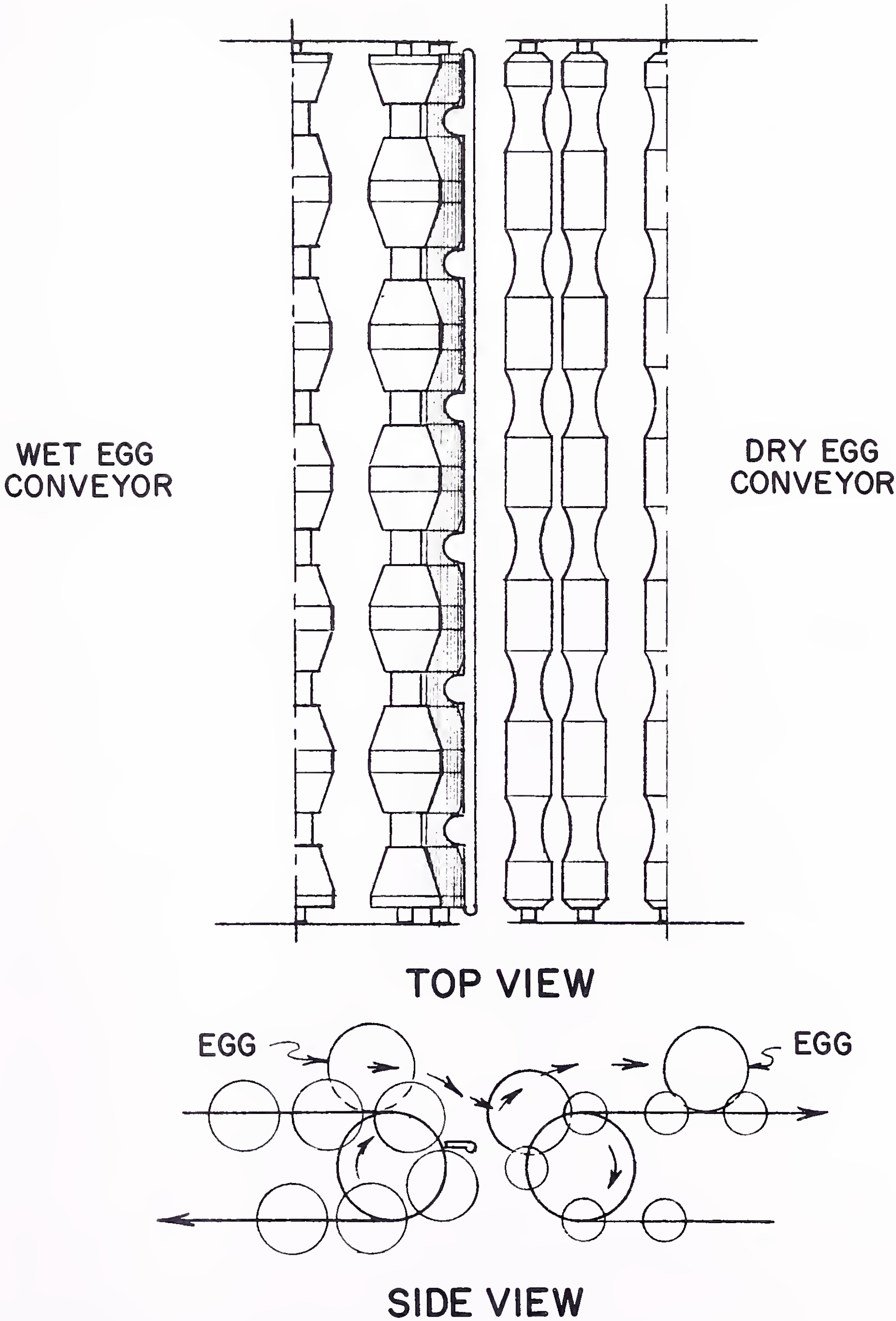


FIGURE 5.—Schematic drawing of a mechanical transfer device that moves eggs from the wet conveyor to the dry conveyor.

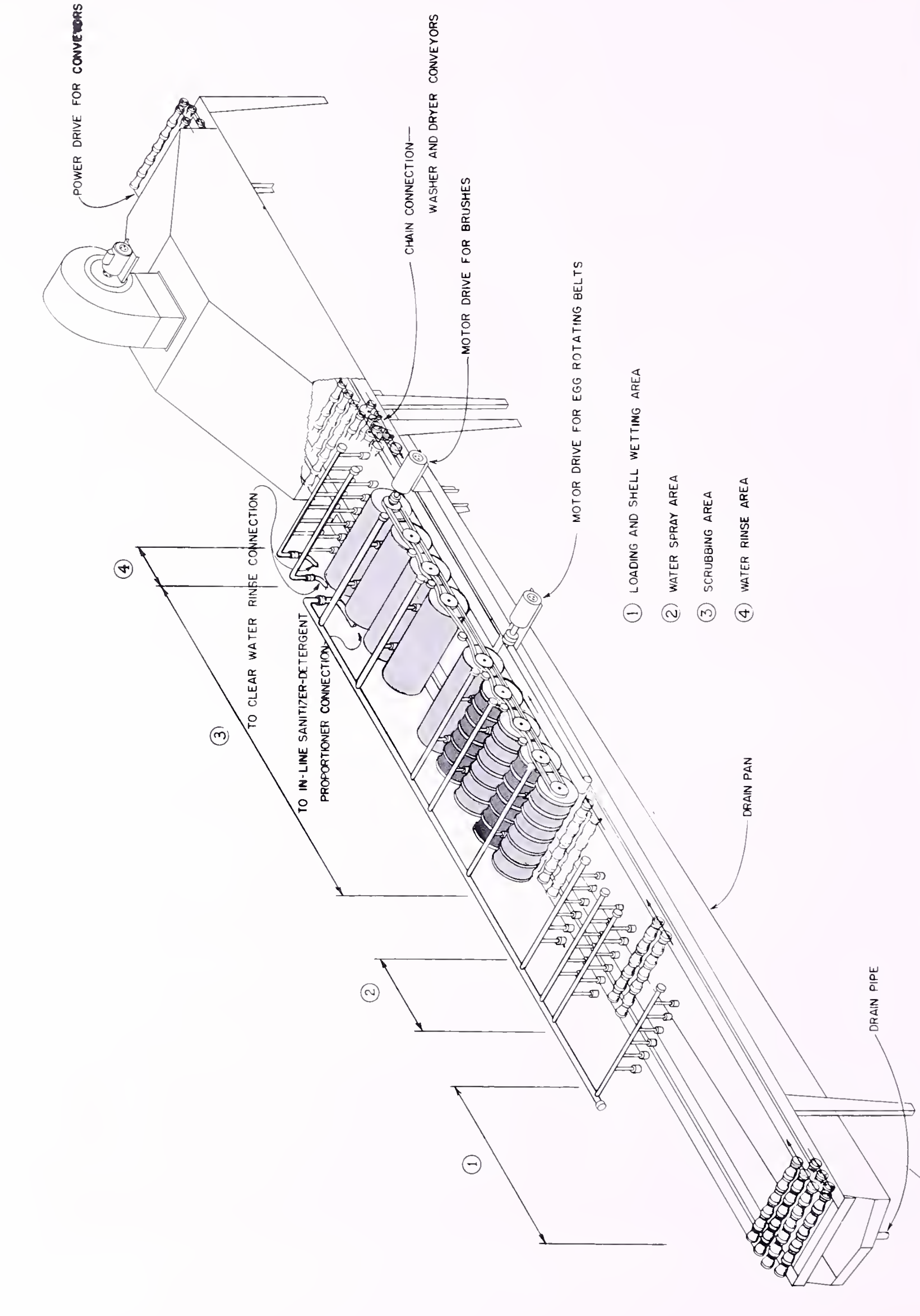


FIGURE 6.—Schematic drawing (isometric) of the experimental egg cleaner.

In the egg loading and shell wetting area, the moisture from the conveyor was transmitted to the eggs when they were placed on the conveyor. After being loaded, the eggs, six abreast, were conveyed under a bank of six hollow-cone fogger-type nozzles that sprayed water and a detergent sanitizer on the eggs. (See table 9, appendix, for spray nozzle detail.)

The next section of the egg cleaner consisted of three rows of six slit-type cutting nozzles for loose dirt removal. Each of these nozzles was centered over a row of eggs and positioned to spray directly onto an egg during the "stop" portion of the conveyor motion pattern (fig. 7 and table 9, appendix).

The third section consisted of the scrubbing area. This area had nine cylindrical brushes mounted parallel to the conveyor spools, with the drive shafts perpendicular to the direction the eggs traveled. The brushes were rotated at 194 r.p.m. All brushes were approximately 6 inches in diameter and 15 inches long. The first four brushes were shaped to approximately match the contours of six eggs abreast (fig. 8). The last five brushes were cylindrical; that is, they were not shaped to fit the contours of the eggs.

The bristles of the first and third brushes were plain nylon (fig. 9A), and the second and fourth were also nylon, but were coated with an epoxy adhesive and fine-grained sand (fig. 9C). Carborundum dust had been incorporated in the nylon filaments of the last five brushes, during the manufacturing process (fig. 9B). All brushes were of commercial make, consisting of Tynex nylon bristles 0.018 inch in diameter. The bristles were held in place by a metal brush strip that spaced the bristle filaments in a continuous spiral at ½-inch intervals on a ⅝-inch-diameter steel shaft.

Another feature provided in the brush-scrubbing area was a device to rotate the eggs during scrubbing (fig. 10). This device consisted of two 1-inch flat belts driven by a motor. The belts were located one on either side of the conveyor in the scrubbing area between the first and fifth brushes. These belts turned the spools of the conveyor and thus rotated the eggs for maximum exposure to the scrubbing brushes. The eggs were rotated opposite to the rotation of the brushes for increased abrasive effect. The linear speed of the belt which turned the spools was 14 feet per minute.

The rinsing area (fig. 11A), or final section of the washer, consisted of two rows of slit-type cutting spray nozzles. Each of these nozzles was positioned to be directly over the eggs during the "stop" portion of the conveyor's motion pattern. The first row included six spray heads, which discharged directly over the center of each egg in the line of six eggs; the second row had seven spray heads positioned to wash the ends of each egg (fig. 18, appendix).

The water supply for the spray nozzles consisted of separate in-feed water supply lines for cold (tap temperature) and hot (160°F.) water at a pressure of about 40 pounds per square inch. The water supply lines were connected to a mixing device that provided wash water at a constant preset temperature. A water pressure regulator maintained the desired pressure within the system, and a liquid proportioner supplied the detergent sanitizer to the nozzle banks. The nozzle banks for the final rinse were connected to the temperature- and pressure-regulated water

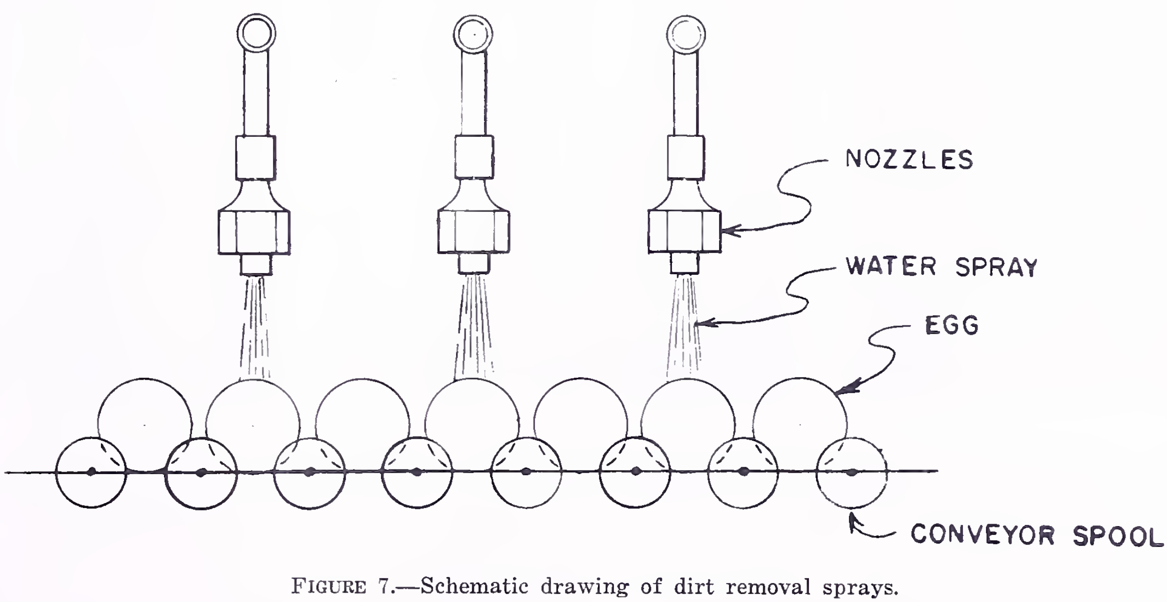


FIGURE 7.—Schematic drawing of dirt removal sprays.

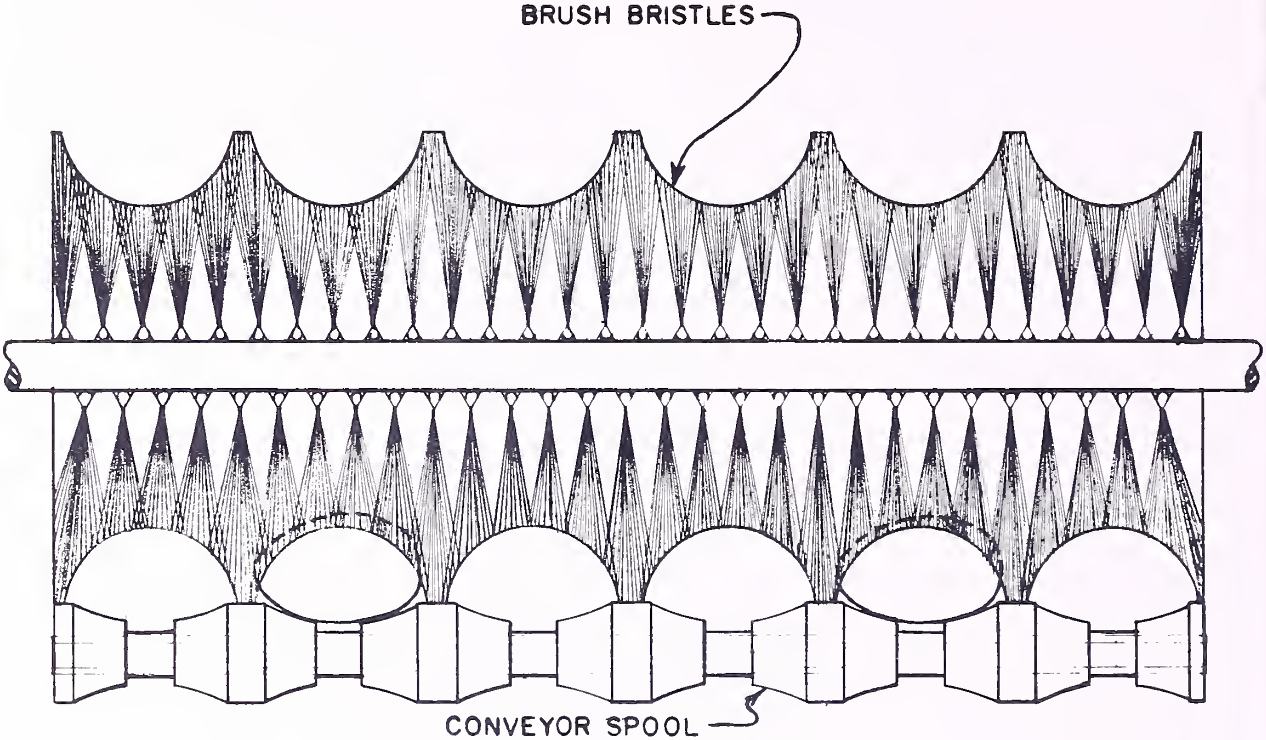
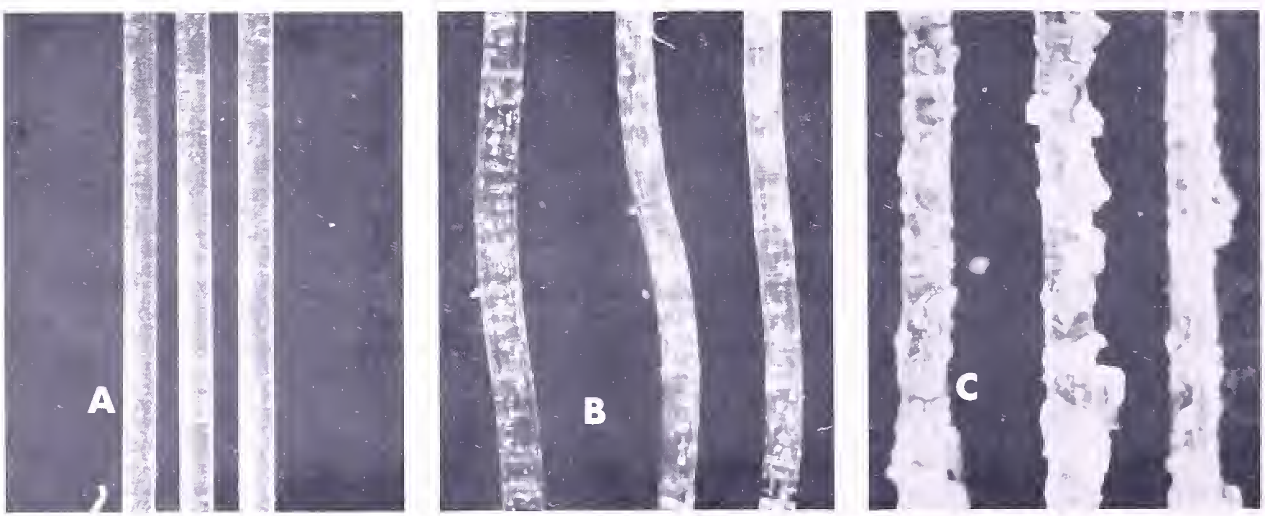


FIGURE 8.—Bristles of this egg cleaning brush are shaped to fit the surfaces of six eggs placed on the conveyor.



(A) BN-25503, (B) BN-25506, (C) BN-25504

FIGURE 9.—Magnification of brush bristles. (A) Plain nylon, (B) nylon with carborundum dust in filament, and (C) nylon coated with epoxy adhesive and fine sand.

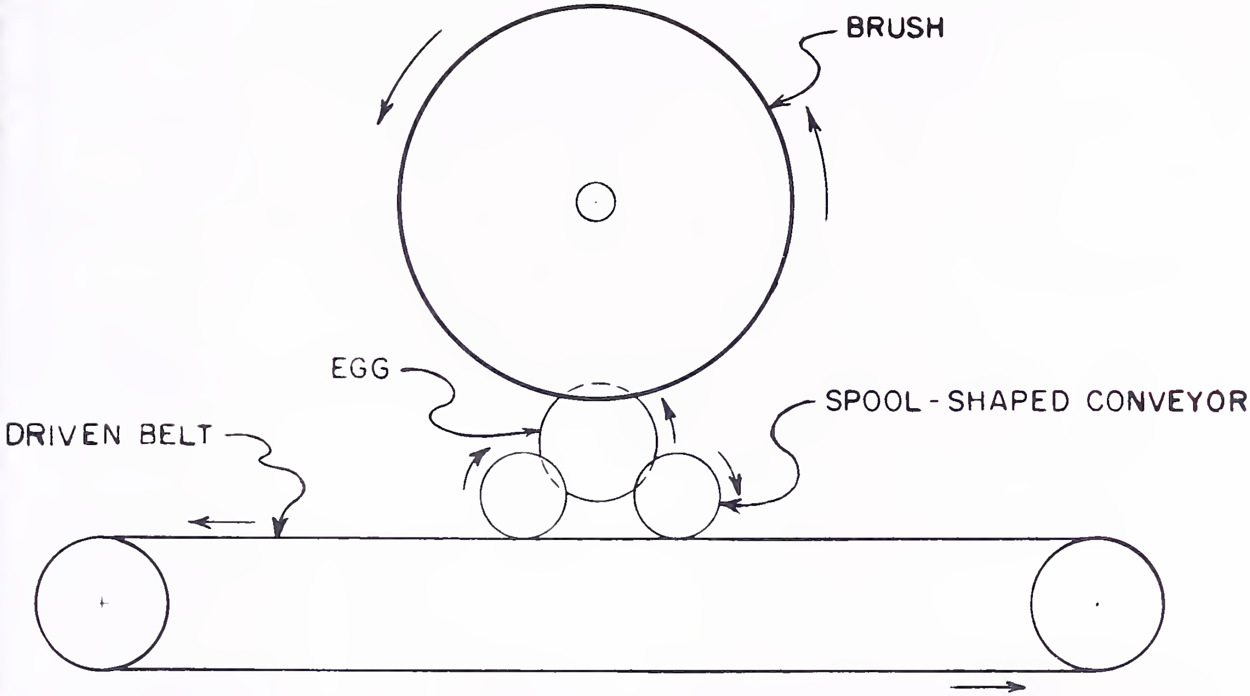


FIGURE 10.—Moving belt below spools of the conveyor rotated the spools and the eggs.

line before the detergent-sanitizer proportioning device, thus a temperature- and pressure-controlled clean water rinse was provided. All nozzles were of high velocity and low volume to provide an adequate force against dirt and stains on the egg shells and to keep water and heating costs at an economical level. Based on the test operation findings, the hourly water consumption was approximately 171 gallons per hour.

Dryer

The dryer, roller, and frame construction was similar to the construction of the washer, being the same height and the same width. A triangular metal hood with a direct motor-driven multiblade air blower covered the conveyor (fig. 11B). Electric heating elements were installed in the blower intake to warm the air during periods of high humidity. The air blower had a capacity of 600 c.f.m. The dryer was designed for direct transfer of the washed and dried eggs to mechanized grading and packing equipment. For most efficient utilization of floor space, the eggs were transferred from the dryer in single file at right angles to the inbound direction of the eggs. Slight modification of commercial conveyors could also provide a right-angle turn or straightaway movement with eggs six abreast.

FIELD TESTS OF EXPERIMENTAL WASHER

The experimental egg washer was installed in a large commercial egg grading and packing plant in central California for testing under conditions that normally prevail in industry. After several trial runs, the equipment was adjusted to run smoothly with the facilities provided. Five experimental lots of eggs were hand-candled to determine original condition and to remove checks. They were then washed on the experimental equipment, recandled and graded for cleanliness score and breakage incidence, and then stored for specified periods before quality and spoilage evaluations were made. Five control lots were handled and stored in the same manner, except that they were not washed.

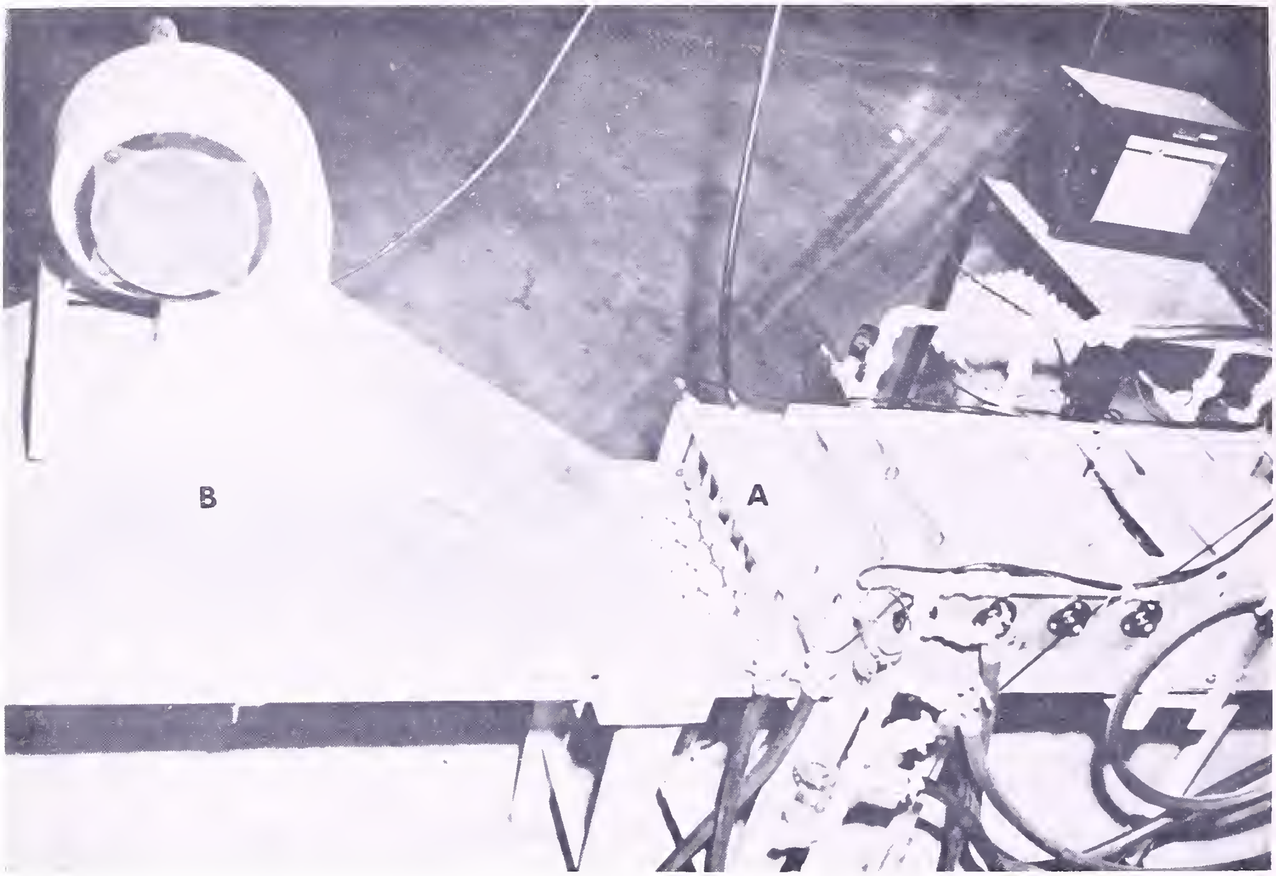


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FIGURE 11.—(A) Rinsing area and (B) drying sections of the experimental egg washer.

Prewashing Selection and Preparation of Eggs

Each lot of eggs to be tested was prepared from 18 cases of nest run eggs approximately 24 hours old. These eggs were obtained from regular plant deliveries and were taken from an individual commercial laying flock which had been in lay from 6 to 8 months.

To insure uniformity between test lots, the eggs were randomized by interchanging filler flat quantities between all cases before determining their original condition.

The randomized eggs from the 18 cases served as a supply for test lots having 2 sublots of 450 eggs each in the following categories: (1) Farm-run eggs, that is, eggs as they arrive at the plant from the farm; (2) farm-run eggs sprayed with a colorless, tasteless mineral oil from an aerosol dispenser at the time of sample preparation; and (3) clean eggs (not oil treated) having a shell cleanliness score required in USDA standards for "A" quality.

The eggs in the two farm-run categories were hand-candled and scored for shell cleanliness in accordance with the USDA standards. The checks, leakers, bloods, and eggs with abnormal shells were removed, and the number of eggs for each shell cleanliness score was recorded. Clean eggs (third category) were selected by candling and were rated USDA grade "A" for shell cleanliness. The test eggs were placed on clean new pulpboard filler flats and put into new fiber cases.

Following the preparation of a test lot, all of the test eggs were stored overnight in the processing plant holding room at approximately 55° F. The following morning, one of the two sublots from each category was washed. The remaining sublot was held as an unwashed control. At the time of washing, the average internal egg temperature for the five lots was 51.6° F. with the temperature for individual lots varying from 48° to 55°.

Washing Procedure

The standard procedure during the tests involved washing 15 cases of regular plant receipt eggs, followed by a sublot of test eggs.[3] Five cases of regular plant receipt eggs were then washed followed by a second sublot of test eggs, and so on. Sublots were washed in a different sequence for each test run.

All test eggs were washed, forced-air dried,[4] removed by hand from the single-filing device at the discharge conveyor (fig. 12),[5] placed on clean, new pulpboard filler flats, and packed in new corrugated fiber cases.[6] The washed eggs were again hand-candled to determine the cleanliness scores after washing and to remove any eggs that had received shell damage during washing.

Observations and adjustments of the equipment were made during the operation to insure consistent operating conditions during a test run. During the tests, the equipment was operated under the following conditions: (1) Eggs were washed at a rate of 20 cases per hour; (2) water was supplied at an average pressure of 24 pounds per square inch (ranging between 20 and 28 p.s.i.), and water consumption averaged 171 gallons per hour; (3) the water temperature at the wetting spray nozzles averaged 95° F. (ranging from 94° to 98°), and a positive temperature gradient of 3° was maintained between the wetting spray and the final rinse with the final rinse water averaging 98°; (4) a detergent-sanitizer solution was mixed into the wash water at a rate of 0.73 ounce per gallon.[7]

After washing each lot, the washed eggs and the unwashed controls were divided into four groups for storage and subsequent quality and spoilage evaluations. The storage space consisted of three laboratory facilities and one commercial egg storage room. For each sublot, 180 eggs were placed into the commercial storage, and the remaining eggs were equally divided between the three laboratory storage facilities. The storage conditions in the laboratories averaged as follows: (1) Temperature 38° F., relative humidity 93 percent, (2) temperature 57°, relative humidity 60 percent, and (3) temperature 77°, relative humidity 20 percent (normal room condition). The commercial storage conditions were typical for egg holding rooms, providing an average temperature of 50° and 63 percent relative humidity.

At the end of each day's operation, the machine was thoroughly cleaned and neutralized.

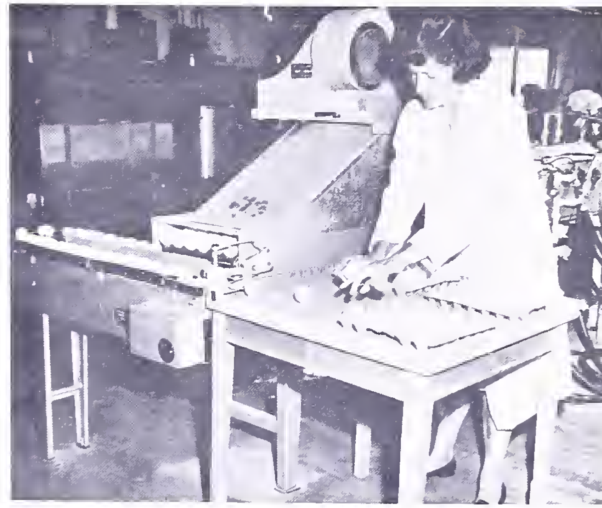

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FIGURE 12.—Cleaned eggs being placed on clean new filler flats.

QUALITY AND BACTERIOLOGICAL DETERMINATION PROCEDURES

On the day after the eggs were washed and after 1, 2, 4, and 8 weeks of storage, samples from each lot were removed from the four different storages for examination; a testing procedure developed for this study and the laboratory study reported earlier[8] was used. Briefly, after each storage period samples were drawn from each of the six categories in each storage condition. These eggs were candled before a standard incandescent candling light and an ultraviolet candling light to remove any eggs checked during storage and any that had developed obvious spoilage. Haugh unit measurements were made; eggs were broken out and the shells and contents examined under the incandescent and ultraviolet lights to determine the presence of fluorescence, off-odors, and rots and mold development; finally, samples of the shells and contents were cultured and plate counts were made.

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[3] This procedure provided sufficient operating time to assure machine and operator competence and to allow for a bacteria buildup which might occur during commercial washing.

[4] Heat was applied to the dryer air whenever the atmospheric conditions prevented the eggs from drying.

[5] To avoid inclusion of packing-machine breakage with breakage caused by washing, all cleaned eggs were removed from the line at the point of transfer from the dryer.

[6] New packing materials were used to minimize shell contamination after washing.

[7] Detergent-sanitizer formulation is given in the appendix.

[8] See footnote 2, p. 4.

RESULTS

Shell Cleanliness

The cleaning effectiveness (defined as the number of stained or dirty eggs cleaned[9] after washing divided by the number of stained or dirty eggs before washing and multiplied by 100) was determined for each of the five test lots. The average cleaning effectiveness achieved or the percent cleaned for the five lots combined was 78 percent (table 1), ranging from a high of 83 to a low of 71 percent. A further analysis (table 2) showed that before washing 3,606, or 80 percent of the farm-run eggs needed cleaning—B and C (stained) and dirty. After washing, 789 eggs, 17.5 percent, still showed stains. From these results the cleaning effectiveness, as defined earlier, may be calculated as

$$\frac{3{,}606-789}{3{,}606} \times 100 = 78 \text{ percent.}$$

TABLE 1.—*Cleaning effectiveness of experimental cleaner and shell damage to natural and oil-treated farm-run eggs and clean eggs during tests in a commercial plant*

Test No.	Dirties before wash[1]	Dirties after wash	Reduction in dirties	Cleaning effective-ness[2]	Incidence of checks[3]			
					Clean eggs	Non-oiled eggs	Oiled eggs	All eggs[4]
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1	80.7	17.1	63.6	78.81	0.93	2.03	2.25	1.73
2	69.8	14.6	55.2	79.08	1.12	1.35	1.59	1.34
3	82.7	23.6	59.1	71.46	2.89	2.67	2.23	2.59
4	84.2	18.9	65.3	77.55	.22	4.28	.89	1.78
5	83.3	14.0	69.3	83.19	1.11	2.00	2.89	2.00
Average	80.1	17.6	62.5	78.0	1.26	2.47	1.97	1.89

[1] Percentage of eggs in B (stain), C (stain), and dirty categories for farm-run and oil-treated farm-run eggs.
[2] Percentage of dirty eggs cleaned.
[3] All eggs with cracked shells were removed before washing.
[4] Includes all farm-run, oil-treated farm-run, and clean eggs washed.

Of the 628 eggs classified as dirty before washing, 346 eggs, or 55 percent, were upgraded to A's or B's after washing. Only 18.5 percent of the eggs classified as dirty remained in that category, but the eggs were retained in this category because of the degree and area of stain rather than because of adhering dirt.

Separate cleaning effectiveness values were developed for the oil-treated and natural groups of eggs (table 3). The average cleanliness scores for the oiled (77.7 percent) and non-oiled (78.4 percent) differed very little.

Interior Egg Quality

The Haugh unit measurement was used to determine the interior quality of the clean, farm-run, and oil-treated farm-run lots of eggs held in storage temperatures of 77°, 57°, 38° and 50° F., for 1 day, 1 week and 2, 4, and 8 weeks (table 4). The difference in interior egg quality for the four different storage room conditions was as expected; that is, the albumen quality deteriorated more rapidly at the higher temperatures. No appreciable effects of washing were noted; however, the washed oil-treated samples consistently maintained slightly higher average Haugh unit values than the washed natural samples.

[9] USDA standards of quality (cleanliness) scores for A, B, C, and dirty eggs, as given in REGULATIONS GOVERNING THE GRADING OF SHELL EGGS AND UNITED STATES STANDARDS, GRADES, AND WEIGHT CLASSES FOR SHELL EGGS, EFFECTIVE JULY 1, 1964. U.S. Dept. Agr. January 1965.

TABLE 2.—*Cleanliness score of farm-run eggs, oil-treated and natural, before and after washing during tests of experimental cleaner in a commercial plant*

Cleanliness score and shell condition[1]	Before wash	After wash
	Number of eggs	*Number of eggs*
A's	894	3,576
B's	1,812	507
C's	1,166	166
Dirties	628	116
Checks	------	99
Broken other than by the machine	------	36
Total	4,500	4,500

[1] Scored in accordance with USDA standards of quality for individual shell eggs.

TABLE 3.—*Cleaning effectiveness of experimental cleaner on farm-run eggs, natural and oil-treated, during tests in a commercial plant*

Test No. and shell treatment	Incidence of soiled eggs[1]			
	Before wash	After wash	Change	Cleaning effectiveness[2]
Natural shell:	*Percent*	*Percent*	*Percent*	*Percent*
1	81.3	21.2	60.1	74.0
2	68.7	13.9	54.8	79.8
3	78.7	19.1	59.6	75.7
4	81.8	18.2	63.6	77.7
5	80.0	12.0	68.0	85.0
Average	78.1	16.9	61.2	78.4
Oil-treated shell:				
1	80.0	13.0	67.0	83.7
2	70.9	15.4	55.5	78.3
3	86.7	28.1	58.6	67.5
4	86.7	19.7	67.0	77.3
5	86.7	16.0	70.7	81.5
Average	82.2	18.4	63.7	77.7

[1] Percentage of farm-run eggs in B, C, and dirty categories.
[2] Percentage of dirty eggs cleaned.

TABLE 4.—*Average Haugh unit scores of washed and unwashed eggs stored at 4 temperatures for 1 day, 1 week, and 2, 4, and 8 weeks during tests of experimental cleaner in a commercial plant*

Storage temperature and period	Unwashed eggs			Washed eggs		
	Clean	Natural farm-run	Oil-treated farm-run	Clean	Natural farm-run	Oil-treated farm-run
	Units	*Units*	*Units*	*Units*	*Units*	*Units*
77° F.:						
1 day	71.2	71.4	74.7	71.4	70.0	73.4
1 week	45.0	45.8	59.2	53.6	51.9	55.0
2 weeks	35.0	29.2	42.0	33.8	30.8	37.1
4 weeks	22.9	21.8	23.8	27.6	19.8	39.8
8 weeks	0	0	0	0	0	0
57° F.:						
1 day	71.2	71.4	74.7	71.4	70.0	73.4
1 week	64.2	67.6	69.6	63.8	64.8	66.5
2 weeks	61.7	60.5	67.3	62.2	62.4	61.8
4 weeks	51.9	52.7	57.4	51.3	52.4	58.7
8 weeks	38.8	41.7	50.6	36.8	36.7	45.7
38° F.:						
1 day	71.2	71.4	74.7	71.4	70.0	73.4
1 week	72.4	66.5	73.4	68.5	68.4	72.9
2 weeks	71.8	69.8	65.9	64.1	71.8	70.6
4 weeks	66.4	64.9	70.8	67.8	67.4	66.9
8 weeks	63.8	65.1	67.7	65.9	66.0	65.2
50° F. (Comm.)						
1 day	71.2	71.4	74.7	71.4	70.0	73.4
1 week	68.9	70.4	72.1	67.6	69.3	68.4
2 weeks	67.3	67.1	69.7	65.5	68.3	69.1
4 weeks	62.0	66.6	66.3	63.5	63.8	65.7
8 weeks	55.7	56.8	58.2	55.3	57.7	56.8

Shell Damage

The incidence of eggs with cracked shells shown in table 1 for the five tests averaged 1.89 percent, ranging from a low of 1.34 percent to a high of 2.59 percent. In the lot with 2.59 percent checks, most of the checked eggs were confined to two flats and were probably cracked during the manual handling between hand-candling and washing. Excluding this one lot, the average was 1.71 percent checks. Examination of the shell damage showed that the lowest percentage of cracks occurred in the clean eggs with the oiled farm-run eggs second; the natural farm-run eggs had the greatest number of checks.

Spoilage and Bacterial Contamination

By treating all of the washed eggs from all storage categories as one group and all the control eggs as one group, the spoilage percentages after 8 weeks were 0.4 percent for the washed and 0.1 percent for the control eggs. The highest percentage occurred in the washed natural and oiled farm-run eggs in commercial storage, both of which showed 0.6 percent. These figures indicate that the spoilage for eggs washed in the experimental cleaner was negligible when the eggs were stored under commercial conditions for 8 weeks.

The bacterial counts for the shells and contents (table 5) were considered to be typical, in that the longer the storage period the greater the number of bacteria, and that the shells contain more bacteria than the contents. Since the samples from the different holding rooms were combined, it would seem likely that the bacteria encountered came from eggs held at the highest storage temperature.

TABLE 5.—*Bacterial counts of unwashed and washed eggs after storage in laboratory and commercial storages during tests of experimental cleaner in a commercial plant*

Treatment and storage time	Clean eggs		Non-oiled farm-run eggs		Oiled farm-run eggs	
	Lab.[1]	Comm.[2]	Lab.[1]	Comm.[2]	Lab.[1]	Comm.[2]
Bacteria per gram of shells						
Unwashed:						
1 week	72	0	1,430	0	7	53
2 weeks	0	53	48,550	865	2,600	1,309
4 weeks	141	0	13,000	1,060	13	596
8 weeks	0	460,000	8,610	14	35,000	162,000
Washed:						
1 week	285	155	14,785	538	2,000	1,149
2 weeks	67,180	435	0	1,611	0	2,280
4 weeks	0	261,800	137,542,200	1,479	43,511	89,560
8 weeks	6,420,100	836,200	3,309,000	1,121,100	0	99,840
Bacteria per ml. of contents						
Unwashed:						
1 week	0	0	0	0	0	0
2 weeks	0	0	0	200	1,820	0
4 weeks	0	0	0	150	100	0
8 weeks	0	0	714	0	0	0
Washed:						
1 week	0	0	14	0	0	0
2 weeks	0	0	1,170,000	0	0	0
4 weeks	90	80	0	0	31,900	0
8 weeks	540	8,000	0	840	0	0

[1] Eggs of clean, natural farm-run, and oil-treated farm-run held in the different laboratory storages, all groups combined.

[2] Eggs of clean, natural farm-run, and oil-treated farm-run held in the commercial storage, all groups combined.

CONCLUSIONS

To develop meaningful conclusions on the results of this research, the performance of the experimental cleaner in a commercial egg grading and packing plant was compared with commercial cleaner performance in the first phase of the research. The criteria used in the comparison involve the basic requirements fundamental to egg cleaning, as follows: (1) Both adhering dirt and stains must be removed from the shell during the washing operation for the eggs to be considered clean; (2) shell damage caused by machines during the cleaning operation must be kept at an extremely low level; and (3) hazards to interior quality from penetration of bacteria, effect of heat, or mechanical treatment must be held at a bare minimum.

The results of the tests on the experimental machine (tables 1 through 5) were compared with results from commercial washers (table 6, 7, and 8) previously reported from this study.[10] As shown in figure 13, the experimental washer cleaned more eggs and damaged fewer eggs than the average commercial machine.

[10] MRR–740. (See footnote 2.)
WALTERS, ROGER E., BRANT, A. W., HAMANN, J. A., and ROBBINS, R. O. NEW DESIGN FEATURES FOR COMMERCIAL EGG WASHERS. Unpublished report before ASAE, December 1964.

TABLE 6.—*Cleaning effectiveness of commercial egg washers and shell damage during tests*[1]

Machine[2]	Plant No.	Dirties before wash[3]	Dirties after wash[3]	Reduction dirties[3]	Cleaning effectiveness	Total increase in cracks and lost eggs by washing[4]
		Percent	*Percent*	*Percent*	*Percent*	*Percent*
A	1	100	91.5	8.5	[5] 8.5	5.3
A	2	100	47.0	53.0	[5]53.0	7.8
B	3	100	49.2	50.8	50.8	2.1
C	4	100	50.0	50.0	[5]50.0	2.8
C	5	100	98.3	1.7	[5] 1.7	4.3
D	3	100	22.3	77.7	77.7	1.7
D	6	100	55.0	45.0	[6]45.0	3.3
D	6	100	86.4	13.6	[6]13.6	1.9
E	1	100	77.9	22.1	22.1	3.1
F	7	100	71.2	28.8	28.8	1.3
G	8	100	15.3	84.7	84.7	3.9
H	9	100	92.9	7.1	7.1	5.0
I	10	100	79.7	20.3	20.3	2.0
Average	—	100	64.1	35.9	35.9	3.4

[1] Based on table 4 in MRR No. 740.
[2] Machines are not identified as to type because of manufacturer identification.
[3] Combined 1, 2, 3, and 4 scoring. (See MRR–740.)
[4] Percent cracked and lost after washing minus percent cracked before washing.
[5] The difference in cleaning effectiveness between plants using the same machine was due to a difference in machine operation and the degree of dirt on the eggs.
[6] Difference in cleaning effectiveness in the same plant was due to the age of the soil on the shell.

TABLE 7.—*Average spoilage of eggs washed by commercial egg washers during field tests after 8 weeks' storage at 50° F.*[1]

Egg classification	Sample size	Average spoilage
	Number	*Percent*
Unwashed controls	55	1.8
Washed dirty eggs	220	5.9
Washed clean eggs	220	2.7

[1] Based on findings in first phase of the research.

TABLE 8.—*Bacterial count in eggs washed in commercial egg washers after 4 weeks' storage at 55° F.*[1]

Machine[2]	Bacteria per gram of shells			Bacteria per ml. of contents		
	Unwashed controls[3]	Clean eggs, washed	Dirty eggs, washed	Unwashed controls[3]	Clean eggs, washed	Dirty eggs, washed
A	—	467	935,000,000	—	0	65,000,000
A	193	5,120	13,600,000	0	8,130	41,000
B	—	0	0	—	0	0
C	—	153,500,000	166,500,000	—	65,000	11,000
C	132	5,970,000	20,800,000	575	2,160	1,202,000
D	0	28,600	6,450,000	0	5,900	420
D	1,220	0	9,050	0	0	0
D	[4]17,000	[4]34,027,000	[4]12,666,000	0	76,500	3,575,000
E	1,340	30,200	78,500,000	1,740	0	19,000,000
F	0	0	1,230	0	0	0
G	25,000	0	2,083,000	0	0	300
H	0	0	[4]549,000	0	0	0
I	0	0	15,300	0	0	0
Average	4,488.5	14,889,337.5	95,090,275	231.5	12,130	6,833,055

[1] Based on table 5 in MRR 740.
[2] Machines are not identified as to type because of manufacturer identification.
[3] Mixed clean and dirty in farm-run proportions.
[4] Fluorescent colonies on plate.

The shell cleanliness [11] and shell damage recorded for the tests of 13 commercial cleaners averaged 35.9 percent and 3.42 percent, respectively; whereas the experimental cleaner averaged 78.0 percent clean and 1.89 percent checks after washing (fig. 13). It will be noted in table 6 that two of the commercial washers had very good cleaning effectiveness scores. These scores were recorded when washing eggs with very little dirt on the shells. Unfortunately, there are no data from these machines when eggs with more dirt were washed.[12] From these data, it seems quite evident that there is much need for improvement in shell cleaning ability and that the experimental washer offers much of this needed improvement.

Projected to commercial plant production this improvement in cleaning effectiveness and reduction in breakage becomes a sizable economic factor worthy of careful consideration by plant operators who have daily egg washing operations. For example, using differentials of 12 cents a dozen between clean eggs with sound shells and the price of checks and 7 cents between clean and dirty eggs, a plant handling 1,000 cases a day, of which it is necessary to wash 25 percent, could realize a saving of approximately $235 a day on the decrease in grade loss.[13] This is providing, of course, that washing performance used as a basis of comparison is no better than the average for the tests of commercial washers.

The spoilage hazard when graded washed eggs are held for extended periods can be virtually eliminated (reduced from 5.9 percent to 0.6 percent). The extent to which low spoilage favors the experimental cleaner is shown on page 14 and in table 7. The machines, both experimental and commercial, increased the bacterial populations in the shells of the washed eggs (tables 5 and 8) and, to a much less extent, the egg contents.

Based on shell cleanliness, shell damage, and spoilage of eggs washed in the commercial and the experimental egg cleaners, the performance of the experimental cleaner was outstanding (tables 1, 2, 3, and 6). It excelled in every test. More dirt and stain were removed from the shells; fewer shells were damaged; and spoilage was less. The findings show that eggs with uniformly good shells can be washed effectively at a rate of 20 cases per hour with a relatively low volume of water,[14] and with considerably more and harder scrubbing actions than are now the general practice.

The cost of the experimental cleaner and its exact operating costs were not determined. It was designed and constructed as an experi-

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[11] For this evaluation the scoring system for cleanliness used in the analysis of the 13 commercial washers was modified to correspond more nearly to that of the USDA scoring system for soiled shells. Scoring in the tests of commercial washers was—

Clean	(2) ½ of surface covered
Very slightly stained	(3) ¾ of surface covered
(1) ¼ of surface covered	(4) all of surface covered

Eggs in the field tests of the experimental washer were scored in accordance with USDA Regulations Governing the Grading of Shell Eggs and United States Standards, Grades, and Weight Classes for Shell Eggs, Effective July 1, 1964.

A–AA—Shell must be clean. Defined as a shell that is free from foreign material and from stains or discolorations that are readily visible. An egg may be considered clean if it has only very small specks or stains, if such specks or stains are not of sufficient number or intensity to detract from the generally clean appearance of the egg. Eggs that show traces of processing oil on the shell are considered clean unless otherwise soiled.

B—May show slight stains, but no adhering dirt: Provided, that they do not appreciably detract from the appearance of the egg. When the stain is localized, approximately 1/32 of the shell's surface may be slightly stained, and when the slightly stained areas are scattered, approximately 1/16 of the shell's surface may be slightly stained.

C—May have slightly stained areas. Moderately stained areas are permitted if they do not cover more than ¼ of the shell's surface. Eggs having shells with prominent stains or adhering dirt are not permitted.

Dirty—A shell which has adhering dirt, prominent stains, or moderate stains covering more than ¼ of the shell surface.

[12] Although one of the tests of a commercial cleaner (D in table 6) showed a cleaning effectiveness that almost equaled the yield of clean eggs by the experimental equipment, the average effectiveness of the same type of equipment in three different plants was much lower (45.4 percent average compared with a high of 77.7 percent). Another commercial cleaner (G, table 6) showed a higher cleaning effectiveness than the experimental cleaner (84.7 percent compared with 78 percent), but cracked more than twice as many eggs as the experimental cleaner (3.9 percent compared with 1.89 percent).

[13] Computation of savings per day on experimental cleaners vs. commercial cleaners:
78% — 35.9% = 42.1% difference in cleaning ability
250 cases × 42.1% = 105.25 cases, or 3,157.5 dozen eggs
3,157.5 × $0.07 = $221.03
3.42% — 1.89% = 1.53% difference in shell breakage due to cleaning
250 cases × 1.53% = 3.825 cases, or 114.75 dozen eggs
114.75 × 0.12 = $13.77
$221.03 + $13.77 = $234.80.

[14] 171 gallons per hour, which makes nonrecirculation feasible.

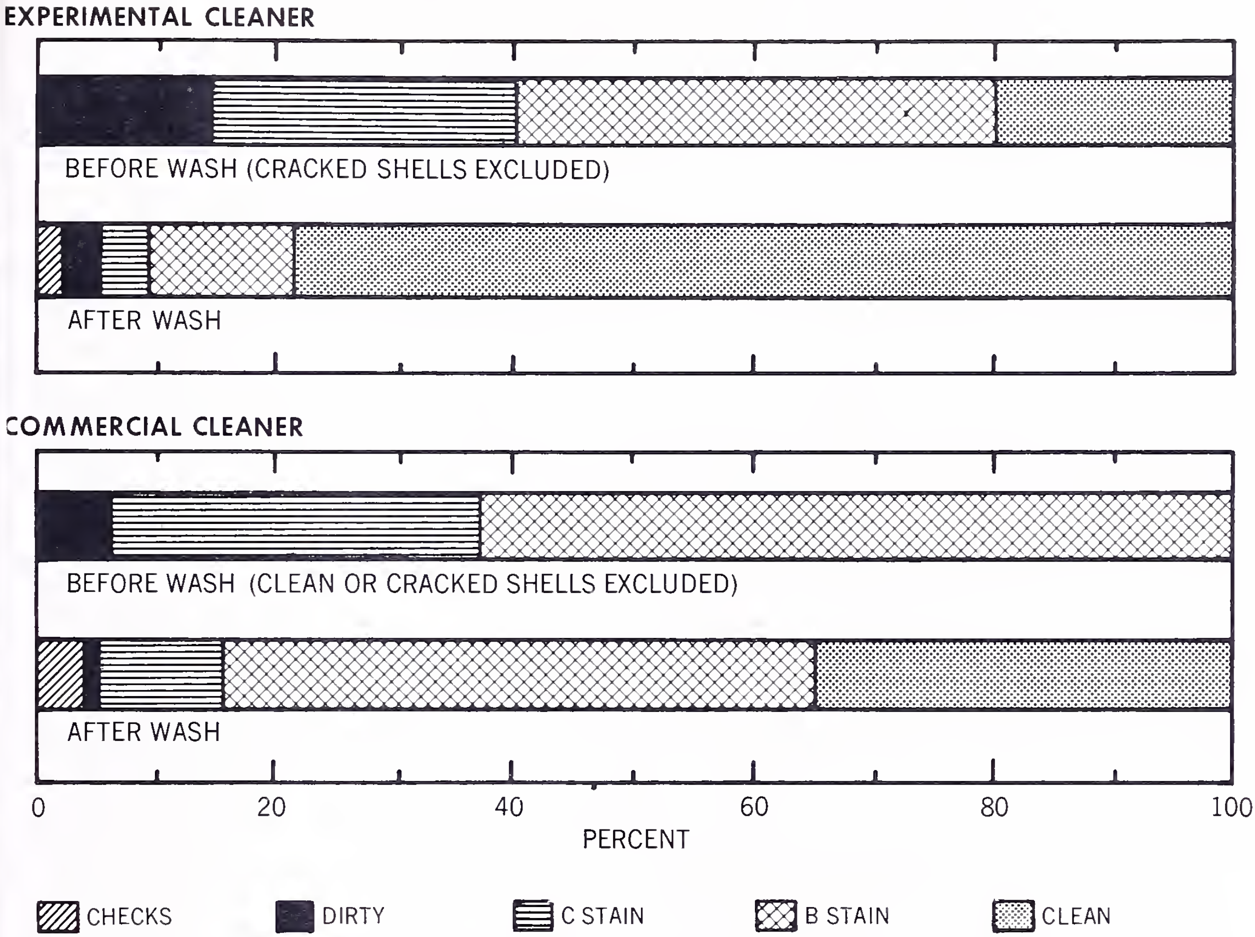


FIGURE 13.—Comparison of cleaning performance and shell damage in experimental and commercial cleaners.

mental single-model unit. It is, however, reasonable to assume that the cost of the cleaner would be comparable to costs of available commercial machines of like capacity because the materials and type of construction are similar. Based on the tests conducted in a commercial egg grading and packing plant, it is also reasonable to assume that the requirements for power, water, water heating, detergent sanitizers, maintenance, and direct labor would be comparable to those of commercial washers with equal production capacity. It is, however, conceivable that the costs of water and of heating could be slightly higher than for available washers, but any such increase would be negligible and would be more than offset by improved operating effectiveness. The 1,368 gallons of water per day required for this washer is very small compared with water demands of food processing plants.

Many of the interactions of the mechanical features combined in the experimental egg washer are not known; some probably will be found to be more important than others, and perhaps lead to further improvements. For instance, it can be seen that the material, diameter, and spacing of the brushes and contact of the brushes with the eggs, and the diameter and spacing of the conveyor spools have considerable effect on the cleaning action and the shell damage while the egg is being scrubbed. Further work on these variables may produce an additional increase in the scrubbing action and ability to clean eggs with still less shell damage.

GENERAL RECOMMENDATIONS FOR CLEANING EGGS

Washing of eggs can be considerably improved if the following precautionary measures are adhered to:

1. Do not attempt to clean excessively dirty eggs.

2. Avoid the use of wash water containing traces of iron; water with an excess of 2 p.p.m. is detrimental to the keeping quality of shell eggs and should not be used.

3. Do not recirculate the wash water.

4. Use odorless cleaning materials.

5. Wash eggs as soon after they are laid as practical.

6. Maintain wash water at a temperature that is at least 20° F. higher than that of the eggs through all washing operations (wetting, cleaning, and rinsing).

7. Moisten eggs with stained shells and adhering dirt before the eggs are submitted to cutting-spray wash and brushes.

8. Precede brushing with a water spray with sufficient force to cut away loose dirt.

9. Augment abrasive power of ordinary brushes with abrasive material in brush bristles.

10. Maintain an accurate control of the sanitizer-detergent level within the wash water.

11. Use a final rinse for the washed eggs.

12. Dry washed eggs completely before packing them.

APPENDIX

TABLE 9.—*Spray nozzles used in experimental cleaner*

Bank No.	Location	Number of sprays	Model No.[1]	Type	Tip No.	Rated gallons per hour each[2]
1	Wetting	6	F–100–C	Cone	2	0.4
2	Cutting	6	F–96–C	Slit	22	3.5
3	Cutting	6	F–96–C	Slit	28	4.1
4	Cutting	6	F–96–C	Slit	28	4.1
5	Brush	2	F–97	Cone	9.0	4.0
6	Brush	2	F–97	Cone	9.0	4.0
7	Brush	2	F–97	Cone	9.0	4.0
8	Brush	2	F–97	Cone	9.0	4.0
9	Brush	2	F–97	Cone	9.0	4.0
10	Rinse	6	F–96–C	Slit	28	4.1
11	Rinse	7	F–96–C	Slit	28	4.1

[1] All these nozzles are manufactured by Monarch Manufacturing Works, Philadelphia, Pa.
[2] Gallons per hour at 20 pounds per square inch.

Cost of Detergent-Sanitizer and Neutralizer

Ortho-phosphoric acid (H_3PO_4) NF grade:

Cost per 7-pound bottle = \$4.50

Cost of 1 fluid ounce $= \frac{4.50}{7 \times 16} \times 1.834$ (specific gravity) = \$0.0736

At metered rate of 0.73 ounce per gallon of a concentration of 7.68 percent for 171 gallons of water per hour, the hourly cost is—
$0.0736 \times 0.73 \times 7.68 \times 171 = \$0.706$

Triton CF–10:

Cost per pound in 480-pound drums = \$0.40

Cost of 1 fluid ounce $= \frac{0.40}{16} \times 1.05$ (specific gravity) = \$0.02625

At metered rate of 0.73 ounce per gallon of a concentration of 3.84 percent for 171 gallons of water per hour, the hourly cost is—
$0.02625 \times 0.73 \times 3.84 \times 171 = \$0.12575$

Total cost of detergent-sanitizer chemicals:

Cost per hour is—

Ortho-phosphoric acid	\$0.70600
Triton CF–10	.12575
Total	\$0.83175

Cost per unit at 20 cases per hour of production is—

1 case $= \frac{0.83175}{20} = \$0.0416$

100 cases = \$4.16

1 dozen eggs $= \frac{0.0416}{30} = \$0.0014$

Cost of detergent-sanitizer neutralizer:

Cost per pound of sodium bicarbonate in 25-pound drums = \$0.20

50-percent solution for ½ hour for 171 gallons of water per hour metered at rate of 0.73 ounce per gallon, the cost per daily washdown is—

$$\frac{0.20 \times 171 \times 0.5 \times 0.73 \times 50}{16} = \$0.39$$

Detergent-Sanitizer Formulation

Concentrate solution:

150 parts = 15% Triton CF–10[1]
300 parts = 30% ortho-phosphoric acid[2]
550 parts = 55% water

Stock solution metered by machine:

256 parts = 25.6% of concentrate solution
744 parts = 74.4% of water

Stock solution metered into wash water at the rate of 0.73 ounce per gallon.

Parts per million in use solution:

Triton CF–10 = 15% × 25.6% = 0.0384
0.73 oz. × 0.0384 = 0.028032
0.028032:128 oz. = x:1,000,000 = 219.0 p.p.m.
Ortho-phosphoric acid = 30% × 25.6 = 0.0768
0.73 oz. × 0.0768 = 0.056064
0.056064:128 oz. = x:1,000,000 = 438.0 p.p.m.

[1] Triton CF–10 is benzyl ether of acetyl phenol liquid nonionic surface active agent with extremely low foaming properties.
[2] Used 85% ortho-phosphoric acid of the NF grade.

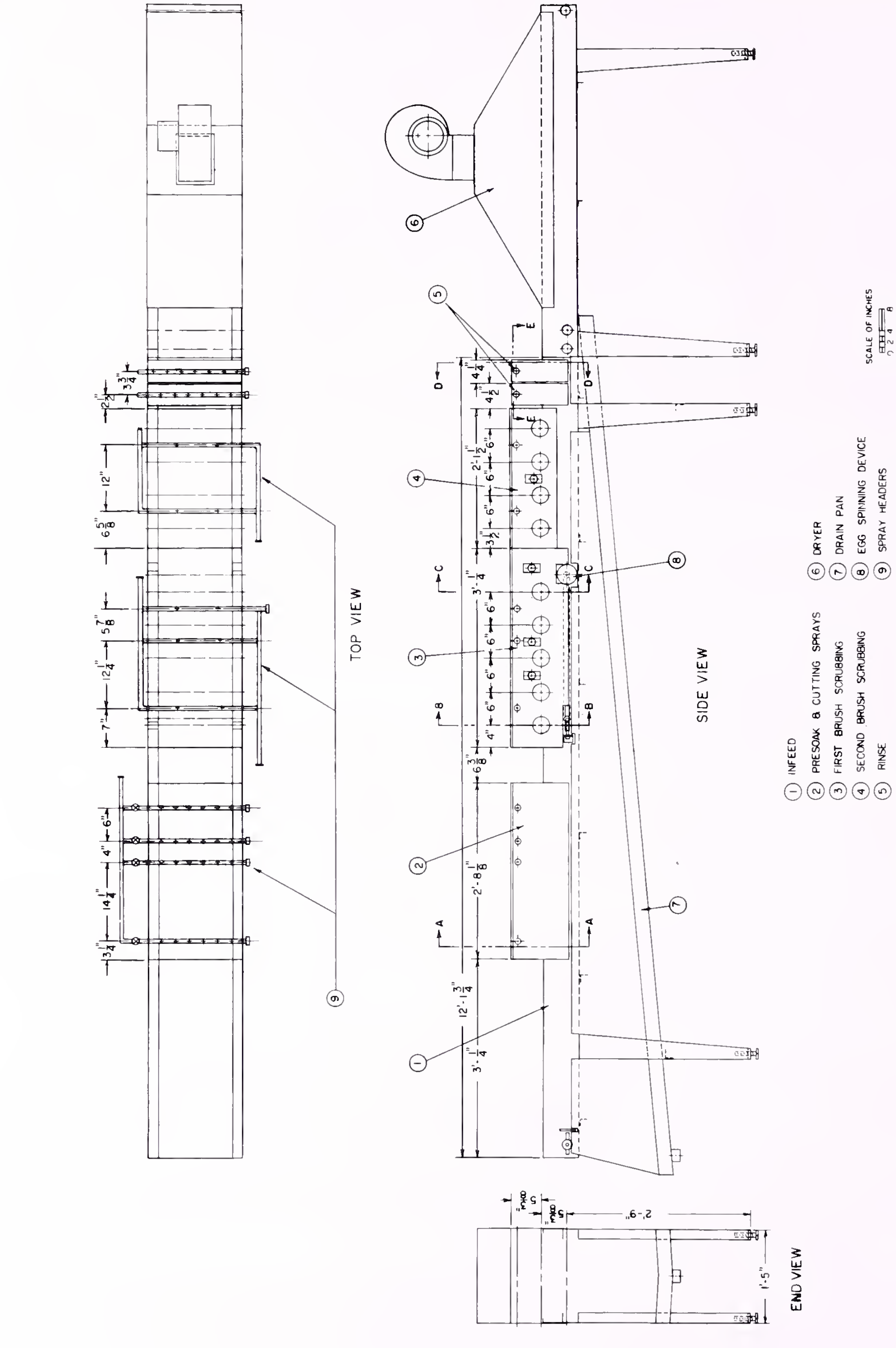
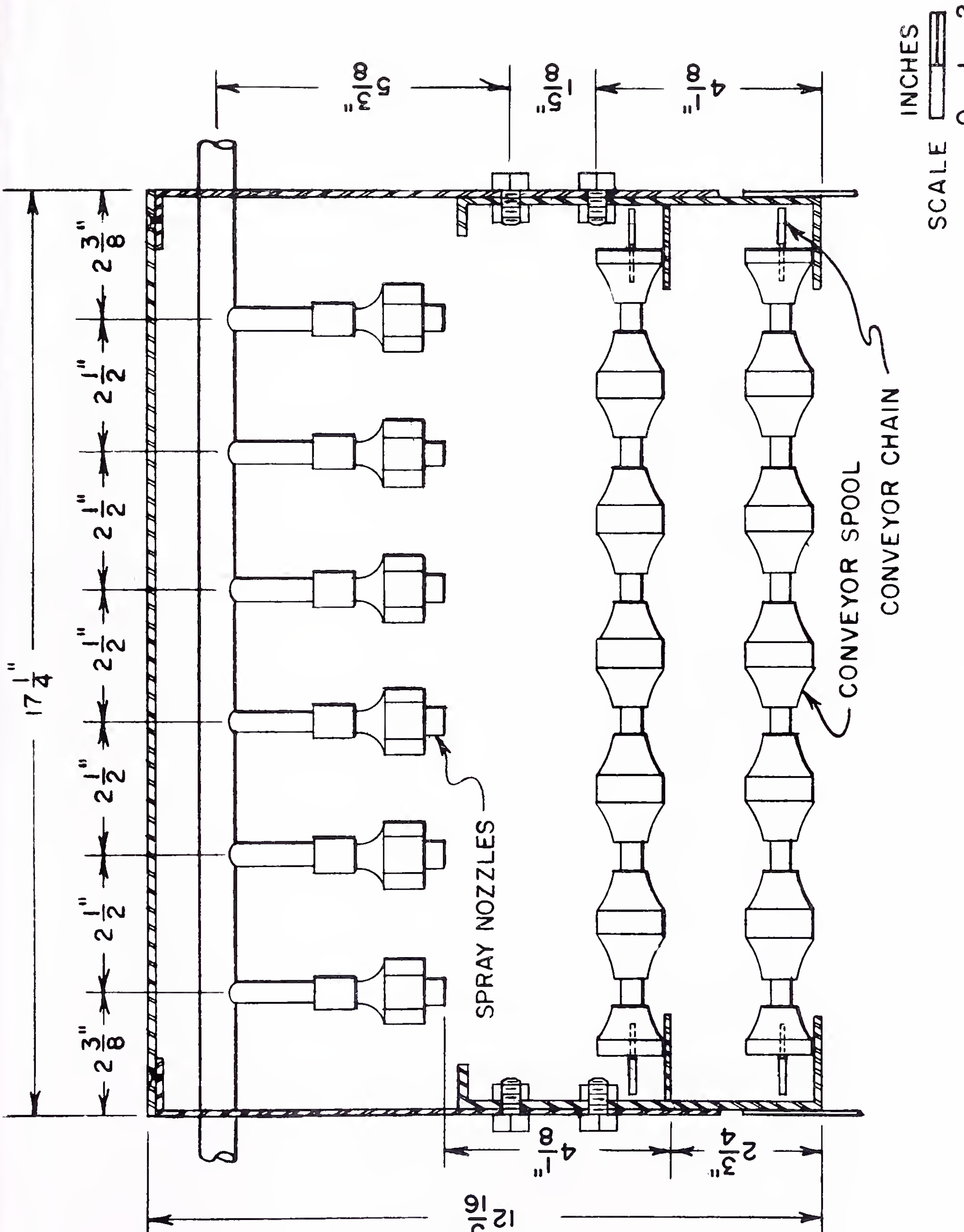


FIGURE 14.—Top and side views of experimental cleaner.



SECTION A-A

FIGURE 15.—View of section A-A of figure 14.

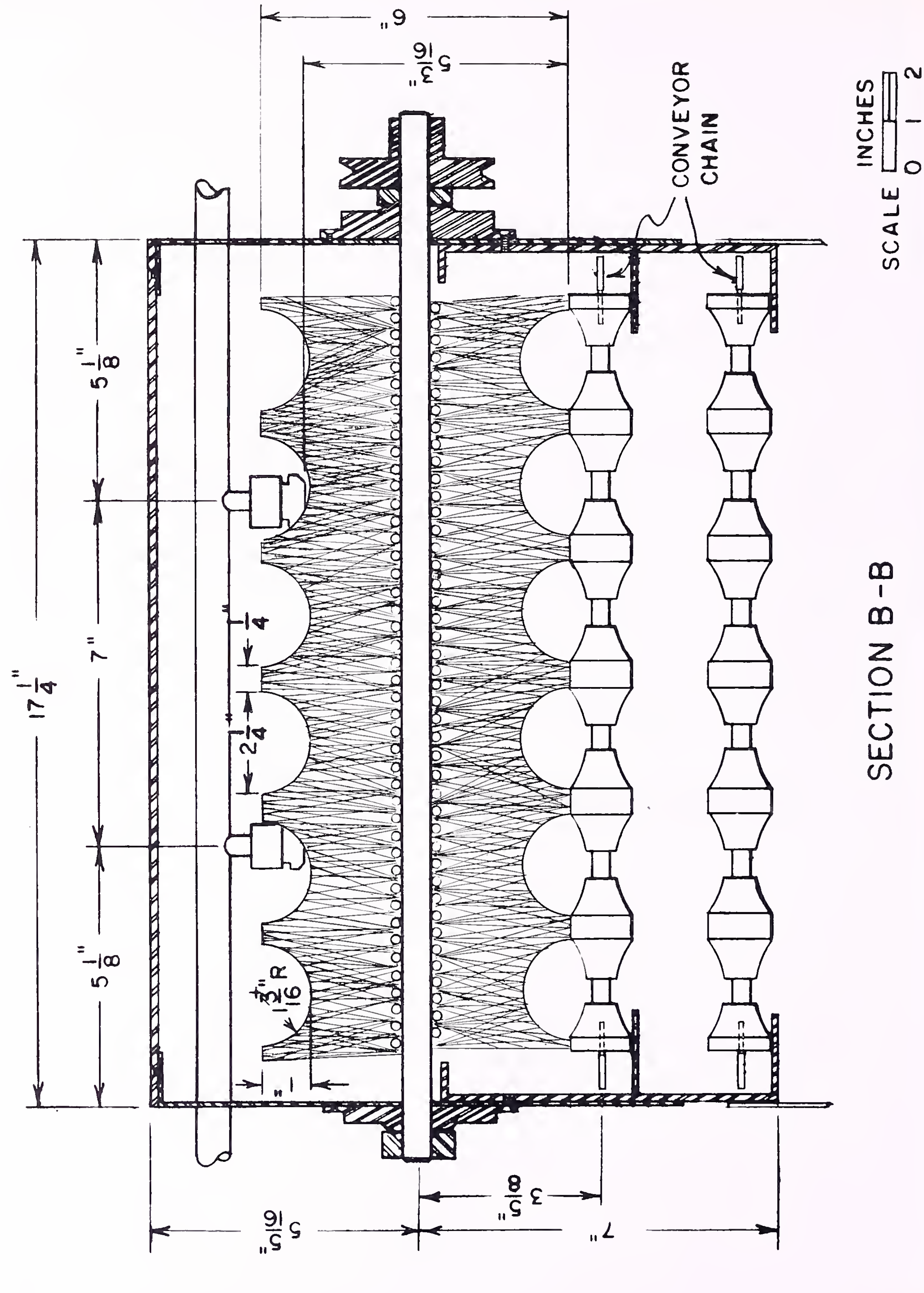


FIGURE 16.—View of section B–B of figure 14.

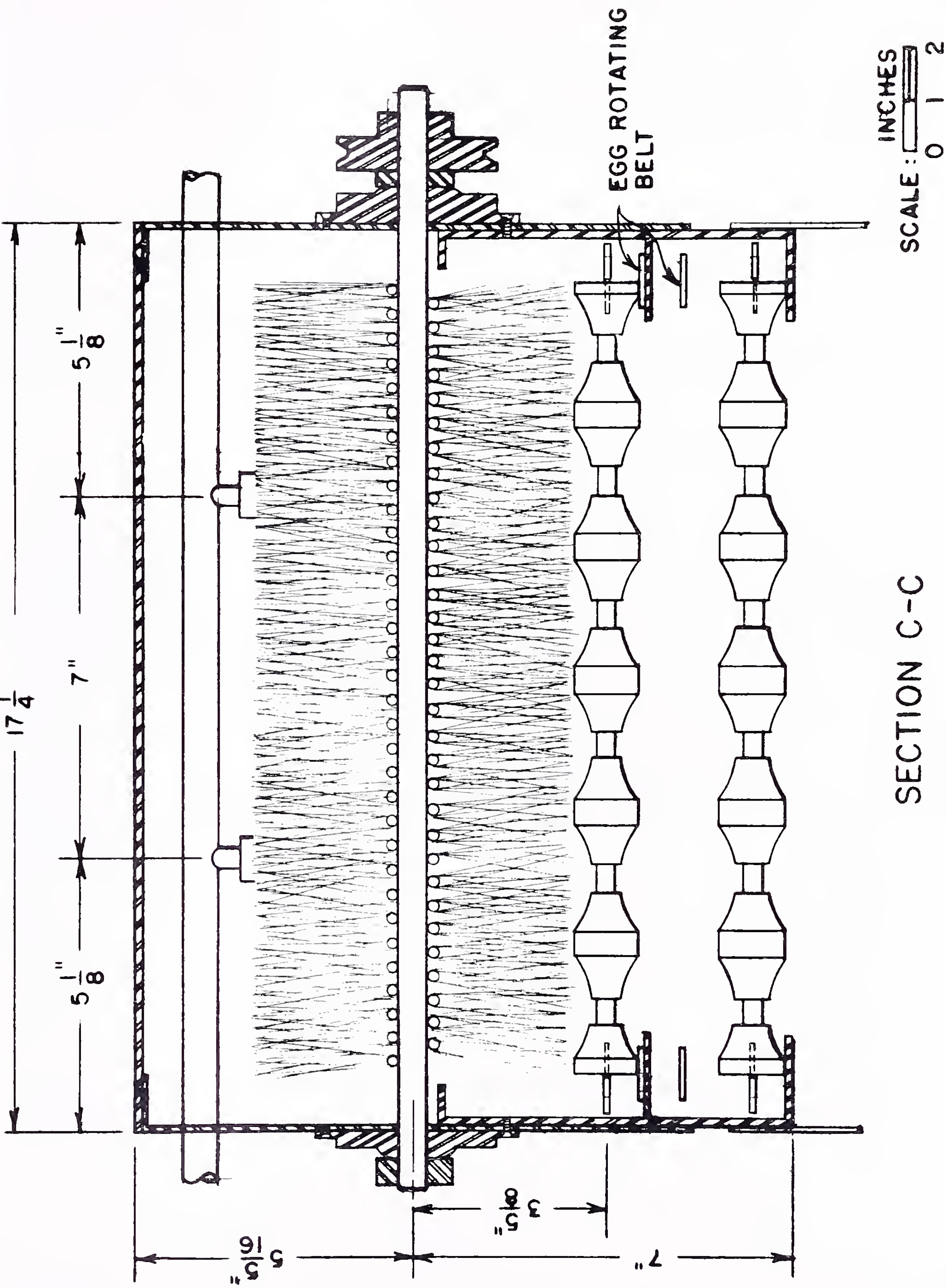


FIGURE 17.—View of section C–C of figure 14.

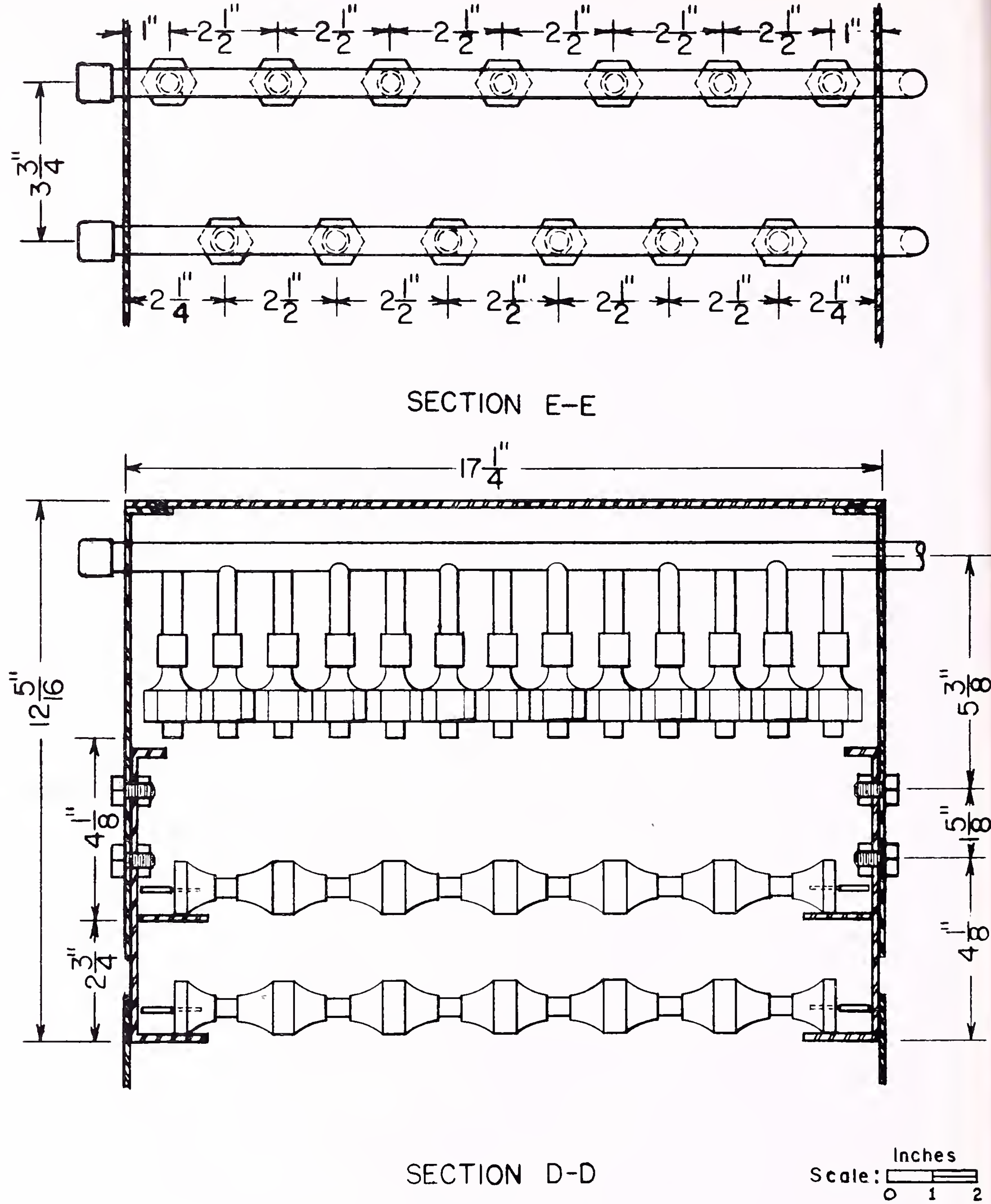


FIGURE 18.—View of sections D–D and E–E of figure 14.

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